MEASURING CHILDREN’S PHYSICAL ACTIVITY AND SEDENTARY BEHAVIORS

Paul D. Loprinzi1, Bradley J. Cardinal2

1Department of Exercise Science, Bellarmine University, Louisville, Kentucky, USA
2Department of Nutrition and Exercise Sciences, Oregon State University, Corvallis, Oregon, USA

The high prevalence of overweight and obesity among children necessitates the need to promote physical activity and reduce sedentary behaviors in children. Consequently, there is a need to be able to reliably and accurately measure physical activity and sedentary behaviors in children. Unfortunately, there is no one measurement tool that captures physical activity and sedentary behaviors perfectly. When choosing a measurement tool to assess physical activity and sedentary behavior, researchers and practitioners must be aware of the strengths and limitations of each measurement. To assist researchers and practitioners in choosing the appropriate measurement tool for the desired study, we overviewed the most common methods currently being used to measure physical activity and sedentary behavior in children, noting the strengths and limitations of each instrument. [J Exerc Sci Fit • Vol 9 • No 1 • 15–23 • 2011]

Keywords: assessment, exercise, measurement

Introduction

The high prevalence of overweight and obesity among children necessitates the need to promote physical activity and reduce sedentary behaviors in children across an array of environmental settings. Consequently, it is important that researchers and practitioners have the ability to accurately and reliably measure physical activity and sedentary behaviors. An accurate and reliable measure of physical activity and sedentary behavior will help us better understand: (1) the association between these behaviors on health outcomes, (2) the dose of physical activity required to elicit favorable health outcomes, (3) determinants of physical activity and sedentary behavior, and (4) the impact of physical activity and sedentary-reducing interventions on the prevalence of overweight and obesity in children. Notably, measuring physical activity in children is particularly challenging as, unlike adults, children’s physical activity patterns are intermittent rather than occurring in continuous time periods (Bailey et al. 1995). As a result, physical activity measures designed specifically for children are necessary to ensure their intermittent activity patterns are captured.

Currently, a wide variety of measures are used to assess the physical activity behaviors of children. The most common methods used include self-report measures such as questionnaires, proxy-report from parents and teachers, and objective measures such as heart rate, accelerometry, pedometers, direct observation, and doubly-labeled water. When determining which method to use, there is no easy choice as each method has strengths and limitations. Factors that influence the selection of a physical activity measurement tool include population (age), sample size, respondent burden, method/delivery mode, assessment time frame, physical activity information required (data output), data management, and measurement error and cost (instrument and administration) (Dollman et al. 2009).

Time spent watching television or engaged with other technologically-based sedentary behaviors, such as computer use or playing video games, are the most commonly measured sedentary behaviors in children. To measure these, data are usually acquired using self-report...
surveys, self-report diaries, parental reporting for children, or direct observation. In the narrative that follows, common methods currently being used to measure physical activity and sedentary behavior in children and adolescents are summarized in greater detail.

Measuring Physical Activity Behavior

Self-report

Self-report measures that are used to evaluate the activity behavior of children include self-administered recalls, interview-administered recalls, and diaries. Self-report measures of physical activity are commonly used in epidemiological research because they are relatively simple to administer, fairly inexpensive, and have the ability to provide information on the type and context of physical activity in a large sample of individuals. However, limitations to the use self-report methods include item interpretation, recall, and social desirability effects. With regard to recall, the sporadic activity patterns and short duration of bouts make it very difficult for children to recall their physical activity behavior (Mattocks et al. 2008). Children often overestimate the amount of time engaged in physical activity, as well as the intensity of their physical activity participation (Hussey et al. 2007).

Several comprehensive reviews have summarized the literature evaluating the reliability and validity of self-report measures developed for children and adolescents (Kohl et al. 2000; Sallis & Saelens 2000; Sallis 1991). Overall, for self-report measures, reliability coefficients ranged from 0.56 to 0.93 and validity coefficients ranged from 0.03 to 0.88. Importantly, lower validity coefficients were observed for children compared to adolescents. Therefore, studies involving children 10 years or younger should rely on objective measures of physical activity, or if this is not feasible, rely on parental reports of child physical activity.

Proxy-report

Children under 10 are not able to accurately or reliably report their physical activity patterns (Saris 1985; Baranowski et al. 1984); therefore, one alternative for estimating the physical activity patterns of children in this age group is to ask parents or teachers to report the child’s activity behavior. Sallis (1991) and Sirard and Pate (2001) have provided a review of proxy reports of child physical activity. Sallis (1991) showed that for proxy reports, activity estimates were moderately correlated with activity monitor counts ($r = 0.41–0.60$). However, there was no association when proxy reports were compared to direct observation and heart rate data. Sirard and Pate (2001) identified three studies examining the reliability and validity of proxy reports of physical activity. For proxy reports by parents ($r = -0.19–0.06$) or teachers ($r = -0.13–0.04$), activity estimates were not associated with direct observation. However, proxy reports by teachers were significantly and positively associated with accelerometry ($r = 0.41–0.66$). When heart rate was used as the criterion measure, significant positive associations were observed for both parent ($r = 0.72–0.82$) and teacher proxy reports ($r = 0.07–0.59$).

Overall, proxy-reporting methods have some promise in providing accurate estimates of young children’s physical activity behavior. Using the parent or teacher as a proxy respondent for young children, recall bias caused by children’s limited cognitive ability can be avoided. However, improving proxy-reporting methods is essential if this type of measure is to be successfully used in large epidemiological research and surveillance studies.

Heart rate

Heart rate monitoring is an attractive approach for assessing physical activity as it provides an objective, but indirect, assessment of the frequency, intensity, and duration of physical activity in children. Additionally, it is relatively inexpensive and unobtrusive. A well-documented problem with using heart rate monitoring is the weak relationship between heart rate and energy expenditure during high and low-intensity levels. Using heart rate monitors may introduce measurement error as most children spend a large percentage of their day in sedentary and light activity (Riddoch et al. 2007). Additionally, the heart rate energy expenditure relationship may be influenced by age, body size, environmental (e.g., ambient temperature and humidity) and emotional stress, and cardiorespiratory fitness. Another limitation of heart rate monitoring is that there is a delay in heart rate response after movement. This may mask the intermittent activity patterns of children.

In an effort to overcome some of these limitations, researchers have used various techniques such as controlling for individual differences in resting heart rate and performing individual heart rate oxygen consumption calibration curves (Kohl et al. 2000). With regard to controlling for individual differences in heart rate, three common approaches have been used: (1) physical activity heart rate (PAHR) index (mean of the recorded heart rate minus resting heart rate), (2) PAHR-25
(percentage of heart rates 25% above resting heart rate), and (3) PAHR-50 (percentage of heart rates 50% above resting heart rate). Importantly, all three of these techniques depend on an accurate assessment of resting heart rate. Unfortunately, there is great variability across studies in the operationalization of resting heart rate and the protocol used to measure resting heart rate (Logan et al. 2000). Depending on the definition or protocol used, estimates of physical activity can vary considerably.

Another approach to assessing physical activity using heart rate monitoring is to create an individual calibration curve by assessing the relationship between heart rate and oxygen consumption for each participant. A common approach for obtaining individual heart rate oxygen consumption curves is using the HR flex method. To estimate oxygen consumption, this method uses the linear prediction equation for heart rates above the HR flex point. For heart rates below the HR flex point, the average of a series of heart rates obtained during rest is used. This method appears to exhibit reasonable accuracy at the group level; however, at the individual level, heart rate-based estimates of energy expenditure, compared with doubly-labeled water, exhibited large differences ranging from −16.7% to 18.8% (Livingstone et al. 1992).

Overall, the strengths of using heart rate monitoring to assess children’s physical activity patterns are that it is an objective assessment that is inexpensive and fairly unobtrusive. However, drawbacks for using heart rate monitoring to assess children’s physical activity patterns include: (1) the variability across studies in the operational definition of resting heart rate and the protocol used to measure resting heart rate, (2) contribution of other factors that influence heart rate, and (3) the impracticality of using heart rate monitoring in large epidemiological and surveillance studies.

**Accelerometry**

Accelerometers have become one of the measures of choice for assessing children’s physical activity. Accelerometers are relatively small (as small as a wristwatch and no larger than the size of a pager), lightweight, and are typically worn around the waist on an adjustable belt. Accelerometers record the frequency and magnitude of the body’s acceleration during movement. As acceleration occurs, the acceleration signal from the accelerometer is digitized and generates an “activity count”. Activity counts are then summed over a predetermined time interval or epoch (e.g., 1 second, 5 seconds, 15 seconds, 30 seconds, 1 minute). The activity count value can then be entered into a prediction equation to estimate physical activity intensity (i.e., sedentary, light, moderate, vigorous) or energy expenditure. Most accelerometers have the battery life and memory capacity to record short epoch data (e.g., 5 seconds) for up to several weeks, making this objective measure ideal for capturing children’s intermittent physical activity.

**Validity**

To date, numerous studies have validated different accelerometers for use in children. Sirard and Pate (2001) reviewed 17 studies investigating the validity of accelerometry in children. Of these, nine studies used a Caltrac accelerometer with direct observation and indirect calorimetry serving as the most frequently used criterion measure. When direct observation was used as the criterion measure, associations ranged from $r=0.16$ to 0.86. For indirect calorimetry, associations ranged from $r=0.80$ to 0.85. The other eight reviewed studies used other accelerometers such as LSI (Large-Scale Integrated Motor Activity Monitor), CSA (Computer Science Application), Tritrac, Mini-logger, and Actical. These accelerometers were also most frequently validated against direct observation and indirect calorimetry. For direct observation, associations ranged from $r=0.58$ to 0.87. For indirect calorimetry, associations ranged from $r=0.37$ to 0.94 for studies using ambulatory activities. One study investigated the validity of the Mini-logger using a cycling protocol and reported a correlation between $r=0.06$ and 0.15. This lower correlation addresses the recognized limitation of accelerometry in that they do not accurately measure activities such as cycling. Overall, studies using indirect calorimetry show a strong positive correlation with accelerometry (i.e., typically greater than 0.7). The large variation in the association against direct observation may be a reflection of the type of activity monitored and large variations in the ages of children being studied.

**Reliability**

With regard to the reliability of accelerometry-based activity monitors, few of the studies reviewed by Sirard and Pate (2001) evaluated evidence of reliability. Of those that did, one study showed the Caltrac and CSA accelerometers had a high correlation ($r>0.86$) between accelerometers placed on the right and left hips (Sallis et al. 1990), whereas another study showed a statistically significant, but not physiologically important, difference between CSA counts from the left and right hips (32 counts·min$^{-1}$ difference) (Fairweather et al. 1990).
1999). During treadmill trials, test–retest reliability (7–13 days) for the Mini-logger ranged from 0.61 to 0.84, and that for the Caltrac accelerometer from 0.76 to 0.80 (Troutman et al. 1999).

**Uni- versus tri-axial accelerometers**

Physical activity patterns of children comprise short bursts of spontaneous play that are episodic (Bailey et al. 1995). It is also thought that children’s intermittent activity patterns involve movement in multiple planes. Because of this, it is suggested that an accelerometer that detects movement in multiple planes (i.e., tri-axial) is more accurate for measuring physical activity intensity than an accelerometer detecting movement in only one plane (i.e., uni-axial). To date, few studies have examined whether tri-axial accelerometers are more accurate than uni-axial accelerometers at estimating energy expenditure or physical activity intensity in children.

Eston et al. (1998) had 30 North Wales children (mean age: 9.3 ± 0.8 years) walk on a treadmill at 4 and 6 km·hr⁻¹ and participate in various play activities (i.e., catch, coloring, and hopscotch) while wearing a Tritrac accelerometer (tri-axial) and ActiGraph 7164 accelerometer (uni-axial). Using indirect calorimetry as the criterion measure, the Tritrac vector-magnitude accelerometer counts \( r = 0.74–0.93 \) and ActiGraph 7164 accelerometer counts \( r = 0.69–0.85 \) exhibited similar correlations.

Also examining the association between accelerometer counts from the Tritrac and ActiGraph 7164, Louie et al. (1999) employed a similar protocol as Eston et al. (1998) by having 21 Chinese boys, aged 8–10 years, walk (4 and 6 km·hr⁻¹) and run (8 and 10 km·hr⁻¹) on a treadmill, play catch, play hopscotch, and color. During these activities, accelerometer and indirect calorimetry were concurrently measured. Overall, when all activities were combined, the correlation between scaled \( VO_2 \) and Tritrac vector-magnitude counts was \( r = 0.94 \); the correlation between scaled \( VO_2 \) and ActiGraph 7164 accelerometer counts was \( r = 0.86 \). For treadmill activities and unregulated play activities, the correlation between scaled \( VO_2 \) and Tritrac vector-magnitude counts was \( r = 0.93 \) and \( r = 0.93 \), respectively. For treadmill activities and unregulated play activities, the correlation between scaled \( VO_2 \) and ActiGraph 7164 counts was \( r = 0.81 \) and \( r = 0.88 \), respectively.

These two studies demonstrate that tri-axial and uni-axial accelerometers report similar correlations with \( VO_2 \). These results are similar to findings from Rowlands et al. (2004) who showed that RT3 counts in the vertical plane did not differ from the RT3 vector magnitude counts among 19 boys (mean age: 9.5 ± 0.8 years) during treadmill (walking at 4 and 6 km·hr⁻¹, running at 8 km·hr⁻¹) and unregulated play activities (i.e., hopscotch, kicking a ball, or sitting). When all activities were combined, the correlation between vertical counts and vector magnitude counts with scaled \( VO_2 \) were \( r = 0.86 \) and \( r = 0.87 \), respectively. For the treadmill trials, the correlation between vertical counts and vector magnitude counts with scaled \( VO_2 \) were \( r = 0.86 \) and \( r = 0.89 \), respectively. For the unregulated play activities, the correlation between vertical counts and vector magnitude counts with scaled \( VO_2 \) were \( r = 0.81 \) and \( r = 0.82 \), respectively.

Overall, the current evidence suggests that tri-axial accelerometers are not superior to uni-axial accelerometers at estimating energy expenditure in children. However, to draw firm conclusions, additional studies are needed that compare the physical activity intensity classification accuracy of tri- and uni-axial accelerometers.

**Epoch length**

As mentioned, children engage in intermittent patterns of play. As a result, epoch length may play an important role in the estimation of time spent at different physical activity intensities. Longer epoch lengths, such as 1 minute, may mask children’s spontaneous, discontinuous patterns of play. This may result in underestimations of time spent at higher intensities (e.g., MVPA).

To date, few studies have examined the effect of epoch length on time spent at different physical activity intensities (Vale et al. 2009; McClain et al. 2008; Nilsson et al. 2002). However, only one study has employed a criterion measure to compare accelerometry estimates against. McClain et al. (2008) had 32 5th grade students (mean age: 10.3 ± 0.5 years) wear an ActiGraph 7164 accelerometer during a single physical education class lasting approximately 30 minutes. During the class, participating children were video-recorded with the videotapes later used for direct observation using C-SOFIT (Computer System for Observing Fitness Instruction Time). Accelerometers were initialized to 5-second epochs and then after data collection, re-integrated up 10-, 15-, 20-, 30-, and 60-second epochs. Accelerometry-derived time spent in MVPA was calculated separately based on count thresholds established by Mattocks et al. (2007), Freedson et al. (2005, 1998), and Treuth et al. (2004). Results showed that for the Treuth and Mattocks cut-points, the shortest epoch
length, 5-second epoch, produced the smallest differences compared to direct observation MVPA. For the Freedson cut-points, all epochs yielded similar mean estimates of MVPA versus direct observation MVPA.

These results suggest that both epoch length and activity count cut-point can influence children’s estimates of MVPA. Future studies using a criterion measure are needed to further examine the effect of epoch length on estimates of physical activity intensity in children.

**Number of monitoring days required**

Researchers are interested in selecting a monitoring protocol that is long enough to reflect children’s habitual physical activity behavior, but not too long that it becomes a burden to participants. To determine the amount of monitoring days required to capture children’s usual physical activity patterns, Trost et al. (2000) had 381 students (n = 92 in grades 1–3; n = 98 in grades 4–6; n = 97 in grades 7–9; n = 94 in grades 10–12) wear an ActiGraph 7164 accelerometer for 7 consecutive days. Spearman-Brown analyses indicated that between 4 and 5 days of monitoring was necessary to achieve a reliability of 0.8 in children, and between 8 and 9 days of monitoring was necessary to achieve a reliability of 0.8 in adolescents. These results indicate that a 7-day monitoring protocol provides reliable estimates of usual physical activity behavior in children and adolescents. Also, significant differences in MVPA were observed between weekend and weekdays; therefore, it is recommended that the monitoring protocol include at least 1 weekend day.

**Calibration studies**

Most investigations using accelerometers to measure children’s physical activity are interested in estimating energy expenditure or quantifying time spent at different physical activity intensities (e.g., MVPA). In an effort to use accelerometer output to estimate energy expenditure or quantify time at different intensities, investigators have developed prediction equations and their respective count cut-points by calibrating accelerometers to some criterion measure (e.g., indirect calorimetry). To date, several prediction equations/cut-points, using regression modeling or receiver operating curves, have been developed for various activity monitors. With the existence of multiple count cut-points, researchers must choose between count cut-points when reducing accelerometer data to estimates of physical activity intensity. Unfortunately, they must make this choice in the absence of any population-based study simultaneously comparing the influence of the different cut-points on estimates of time spent in sedentary, light, and MVPA intensity.

In general, prediction equations/cut-points do not accurately estimate energy expenditure at the group or individual level; however, the majority of prediction equations/cut-points do a reasonable job of correctly classifying MVPA in children. Differences among cut-point values for each accelerometer may be a function of the differences in the age range of participants, differences in activities studied, and differences in the measurements systems used. The existence of multiple cut-points makes it hard for researchers to decide which cut-point to use when reducing accelerometry data. As a result, making comparisons between studies is difficult.

Freedson and colleagues (2005) introduced an approach to accelerometer data processing that aims to indentify patterns in accelerometer data and use modeling to interpret the patterns found. Although speculative, using pattern recognition models may prevent some of the misclassification of activity intensity that often occurs when using activity count thresholds. Additional research on the development and validation of this approach is needed before widespread adoption occurs.

**Pedometry**

A cost-effective and well-tolerated alternative to accelerometers and heart rate monitors is to measure physical activity using a pedometer, which estimates activity count thresholds. As a result, making comparisons between studies is difficult. Although speculative, using pattern recognition models may prevent some of the misclassification of activity intensity that often occurs when using activity count thresholds. Additional research on the development and validation of this approach is needed before widespread adoption occurs.

Pedometers appear to be a valid measure of physical activity in children. During over-ground self-paced walking and during treadmill trials at comfortable speeds of locomotion (approximately 2.5–3.5 mph), the Digiwalker SW-200 and the Walk4Life 2502 have shown a strong association with steps measured by an observer (ICC > 0.90) (Beets et al. 2005). However, at slower walking speeds (<2.0 mph), there was a lower magnitude of association between pedometer steps and observed steps (Beets et al. 2005). Pedometers have also been compared against accelerometer counts (r > 0.87) (Ramirez-Marrero et al. 2004), oxygen uptake (r = 0.806) (Eston et al. 1998) and heart rate (r = 0.622) (Eston et al. 1998).

In addition to evidence of validity, pedometers appear to demonstrate evidence of reliability in children. Inter-instrument reliability has been assessed by examining differences in pedometer steps between pedometers attached at different locations (e.g., left hip, right hip,
and umbilicus). Although some studies show certain locations to be more accurate (Beets et al. 2005), most studies reported no differences in pedometer steps between attachment sites (Jago et al. 2006; Louie & Chan 2003; Ramirez-Marrero et al. 2002).

Although most pedometers are limited in that they only count the number of steps taken over a given period, they can provide estimates of overall activity, as in most populations, ambulatory movement contributes to the majority of overall activity (Mattocks et al. 2008; De Vries et al. 2006). Because of this, its objectivity, and evidence of reliability and validity, pedometers are well suited for measuring physical activity in children.

**Direct observation**

Direct observation is a method by which a trained observer classifies children’s free-living physical activity by objectively recording their activity behavior for a predetermined length of time. All recordings are entered into a computer-based or paper-and-pencil entry form. Observations typically occur in natural settings such as at home or during school.

Direct observation has a number of advantages over other measurement tools. First, it is an objective method that provides contextually rich data to identify other factors related to physical activity behavior (e.g., physical and social factors). Second, it can provide information on the type and intensity of physical activity. Third, it can be used in a variety of different settings. Lastly, with the development of software packages [e.g., BEST (Behavior Evaluation Strategies and Taxonomies), The Observer], data can be entered directly into a computer, handheld computer, and allow events to be coded directly from a videotape—all of which reduces error and speeds up analyses and reporting (McKenzie 2002). The main disadvantage of direct observation is the time-intensive nature of observer training and data coding.

Various observation systems have been developed and used in measuring the physical activity behavior of children. The CARS (Children Activity Rating Scale) observation system is a commonly used observation instrument where an observer rates the child’s activity intensity level from sedentary to vigorous on a scale of 1 through 5 (1 = stationary – no movement; 2 = stationary – with movement; 3 = translocation – slow/easy; 4 = translocation – moderate; and 5 = translocation – fast). Another commonly used observation system is the OSRAC-P (Observational System for Recording Activity in Children—Preschool Version). This observational system uses the CARS observational instrument to code a focal child’s activity level in a preschool setting. The observer also records the type of activity the designated child is engaged in (e.g., running, walking, climbing), their location (indoors, outdoors), whether prompts for activity are occurring, and contextual factors such as playing in a group or solitary. Unlike CARS and OSRAC-P, SOPLAY (System for Observing Play and Leisure Activity in Youth) is an observation system that does not focus on the individual child but rather captures behavioral and contextual information in groups of children. The observer briefly scans the target area recording the number of boys and girls present, the activity level of each sex (sedentary, walking or very active), and the type of activity the children are participating in. Other contextual factors such as the presence of equipment are also recorded.

McKenzie (2002) showed that direct observation is a valid and reliable method for measuring children’s physical activity. In his review, a total of nine observational systems were reviewed, and among these, eight demonstrated evidence of validity. Additionally, all nine demonstrated evidence of reliability with interobserver reliability coefficients greater than 0.84. Specifically, CARS, OSRAC-P, and SOPLAY have all been psychometrically tested. CARS has been validated against indirect calorimetry (Puhl et al. 1990), accelerometry (Finn & Specker 2000; Noland et al. 1990), and heart rate monitoring (Puhl et al. 1990). In terms of reliability, CARS, OSRAC-P, and SOPLAY have all demonstrated evidence of reliability (Brown et al. 2006; McKenzie et al. 2000; Puhl et al. 1990).

When observers are highly trained and follow a specific protocol, direct observation can provide valid and reliable estimates of the physical activity behavior of children. The ability to provide an objective assessment of physical activity as well as providing information on the type and context of physical activity makes direct observation an attractive method for measuring children’s physical activity. Additionally, the use of video recording can increase the reliability of direct observation measurements as well as create a permanent record.

**Doubly-labeled water**

Another criterion measured used to measure children’s physical activity in free-living environments is doubly-labeled water. This method measures total energy expenditure over approximately a 2-week period by directly measuring carbon dioxide production. This involves ingesting a “heavy water” that contains two stable isotopes of water: deuterium-labeled water ($^{2}$H$_{2}$O)
and oxygen-18-labeled water (H₂¹⁸O). After the ingestion of the “heavy water,” deuterium-labeled water is eliminated from the body through water loss (e.g., sweat) while oxygen-18-labeled water is eliminated as carbon dioxide and water loss. The difference between the elimination rates of these two stable isotopes is directly proportional to carbon dioxide production or energy expenditure.

In children and adults, doubly-labeled water has been validated against indirect calorimetry for subjects living in metabolic chambers (Goran 1994). Overall, studies show that the doubly-labeled water technique is accurate within 10%, and consequently, has been considered a criterion or gold standard measure because of its precision.

There are several advantages of doubly-labeled water. First, the technique is noninvasive and provides an unobtrusive measure of energy expenditure in free-living environments. Second, when doubly-labeled water is combined with indirect calorimetry, it can measure individual components of daily energy expenditure. Third, energy expenditure can be assessed up to 2-week time periods. Major disadvantages of doubly-labeled water include the expense (up to US$300 per child), the availability of the stable isotopes, the inability to determine the intensity, duration, and frequency of physical activity, and the inability to differentiate the components of energy expenditure. Given these limitations, the doubly-labeled water technique is not a feasible method for measuring children’s free-living physical activity in large-scale epidemiological studies.

### Measuring Sedentary Behavior

Given the independent association between sedentary behavior and negative health outcomes in adults, such as obesity and type 2 diabetes (Ford et al. 2005; Hu et al. 2003), the study of sedentary behavior and its association with health outcomes in children is emerging. Sedentary behavior is often assessed by the amount of time children spend viewing TV or other screen-based sedentary behaviors, such as computer use or playing video games. However, these sedentary behaviors provide only a partial picture of overall levels of sedentary behavior in a typical waking day (Matthews et al. 2008). For example, Gorely et al. (2007) found that adolescent girls spend about 1 hour doing homework, 45 minutes in motorized transport, and 30 minutes “sitting and talking” during each day of their leisure time (non-school).

Various methods have been used to measure screen-based time, including self-report surveys, self-report diaries, parental reporting for children, and direct observation. Recently, Bryant et al. (2007) evaluated the methods used to measure TV viewing and summarized these methods’ measurement properties. Among the 98 studies reviewed, 80% of the studies measured TV viewing by self-report surveys, 8% used self-reported diaries, 29% used parental report, and 5% used direct observation. Some studies were entered into more than one option; therefore, the percentages within the categories do not add up to 100%. Few of the reviewed studies used a measure that had been psychometrically tested. Of the 98 studies, 14 examined test–retest reliability and 15 assessed some form of validity. Of these, seven studies were assessed for both reliability and validity. Test–retest reliability ranged from $r = 0.13$ (measured 2 weeks apart) to $r = 0.98$ (measured 1 hour apart). Only 4 of the 15 studies assessing validity used an objective measure of TV viewing as a criterion method (e.g., direct observation). The remaining 11 studies reported correlations with other self-reported or objective measures of physical activity. Although it is suggested that TV viewing displaces time that would otherwise be used for physical activity, using a physical activity measure as a criterion measure to validate sedentary surveys is inappropriate. For example, in a meta-analysis by Marshall et al. (2004), only a small negative correlation between physical activity and TV viewing was observed (mean effect size: –0.09).

To provide a better overall assessment of sedentary behavior, objective measures of physical activity, such as accelerometry, have been used (Mitchell et al. 2009; Matthews et al. 2008). Researchers have conducted several calibration studies to determine accelerometer count cut-points for sedentary behavior in children. For preschool-aged children, count cut-points have been developed for the ActiGraph 7164 accelerometer. Sirard et al. (2005) used direct observation as the criterion measure to develop the following count cut-points per 15 seconds in a sample of 16 U.S. preschool-aged children: ≤ 301 (3-year-olds), ≤ 363 (4-year-olds), and ≤ 398 (5-year-olds). Applying the received operating characteristic area under the curve (AUC) standards described by Metz (1978), these sedentary cut-points exhibited excellent classification accuracy (AUC ≥ 0.9). In a sample of 30 Scottish preschoolers, Reilly et al. (2003) used direct observation as the criterion measure and identified sedentary behavior as < 1,100 counts per minute. Sensitivity and specificity were 83% and 82%,
respectively. The cut-points obtained in these studies are quite different, reflecting differences in epoch length (15 seconds vs. 1 minute) and population.

In a sample of 74 13–14-year-old adolescent girls, Treuth et al. (2004) used indirect calorimetry to develop sedentary cut-points for the ActiGraph 7164 accelerometer. The sedentary cut-points were found to be <50 counts per 30 seconds and <100 counts per minute. The lower cut-point of 50 counts per 30 seconds resulted in perfect classification accuracy.

Overall, the findings of these studies indicate that accelerometers provide valid estimates of sedentary behavior in children when the cut-points selected are valid for the population under study. Given the lower epoch length and better classification accuracy, the sedentary cut-points developed by Sirard et al. (2005) are recommended for use in preschool-aged children. For children and adolescents, a sedentary cut-point <100 counts per minute should be used.

Summary

To date, a wide range of methods have been used to measure physical activity in children. These include self-report measures such as questionnaires, proxy-report from parents and teachers, and objective measures such as heart rate, accelerometry, pedometers, direct observation, and doubly-labeled water. When determining which method to use, researchers and practitioners should consider the population (age), sample size, respondent burden, method/delivery mode, assessment time frame, physical activity information required (data output), data management, and measurement error and cost (instrument and administration) (Dollman et al. 2009).

Sedentary behavior is often assessed by the amount of time children spend viewing TV or other “screen-based” activities. Common methods used to measure screen-based time include self-report surveys, self-report diaries, parental reporting for children, and direct observation. Of these methods, it is difficult to draw conclusions as to which method is best given the paucity of research examining the reliability and validity of these measures. Given this, as well as that screen-based time provides only a partial picture of overall levels of sedentary behavior in a typical waking day (Matthews et al. 2008), a better alternative to measure sedentary behavior in children is the use of objective measures of physical activity, such as accelerometry.

References


